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(58) Field of search

F4U

Selected US specifications from IPC sub-class F24H

(54) Heat store system

(57) A method of storing and releasing heat energy uses a reversible chemical reaction in which heating causes dissociation of a chemical compound, the components formed by dissociation being exothermically reactable. An example is calcium hydroxide, which dissociates to calcium oxide and water (in the form of steam) when heated to about 580°C. Apparatus is provided for carrying out the reaction, the apparatus comprising a chamber (22) in which the compound is heated, and separating means (27, 28, 29 and 31) for removing one of the components formed by dissociation (water). On reintroducing the water to the chamber, heat is evolved, which is recovered by a heat exchanger.

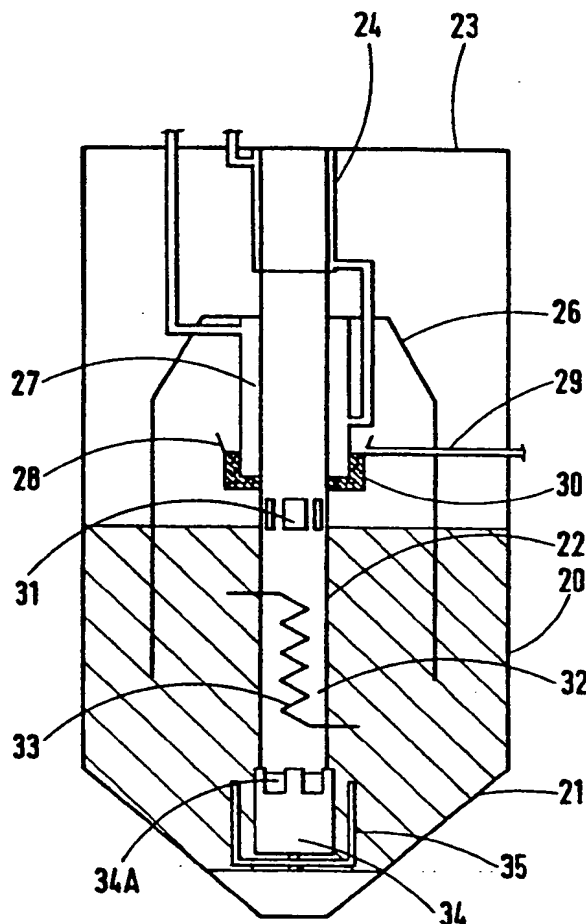


Fig.2

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

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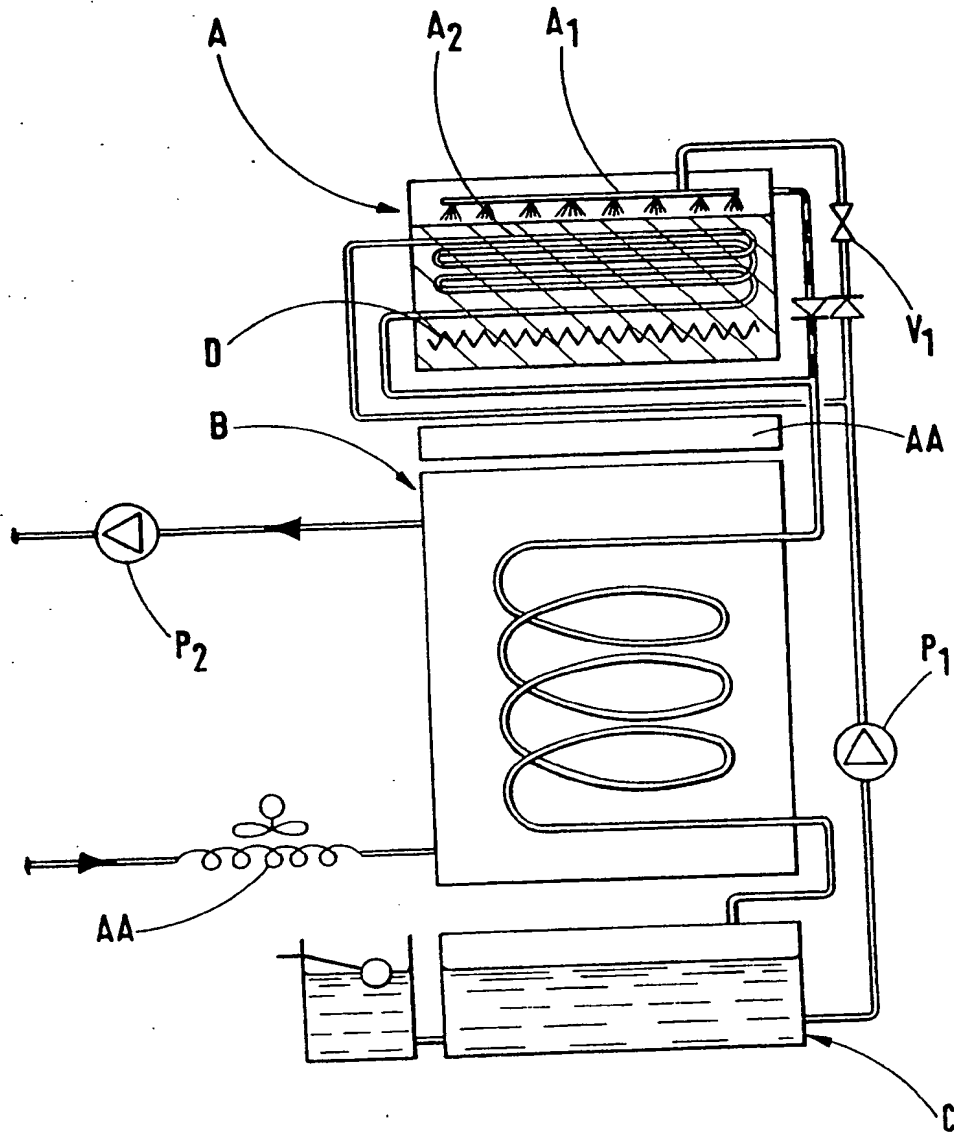


Fig.1

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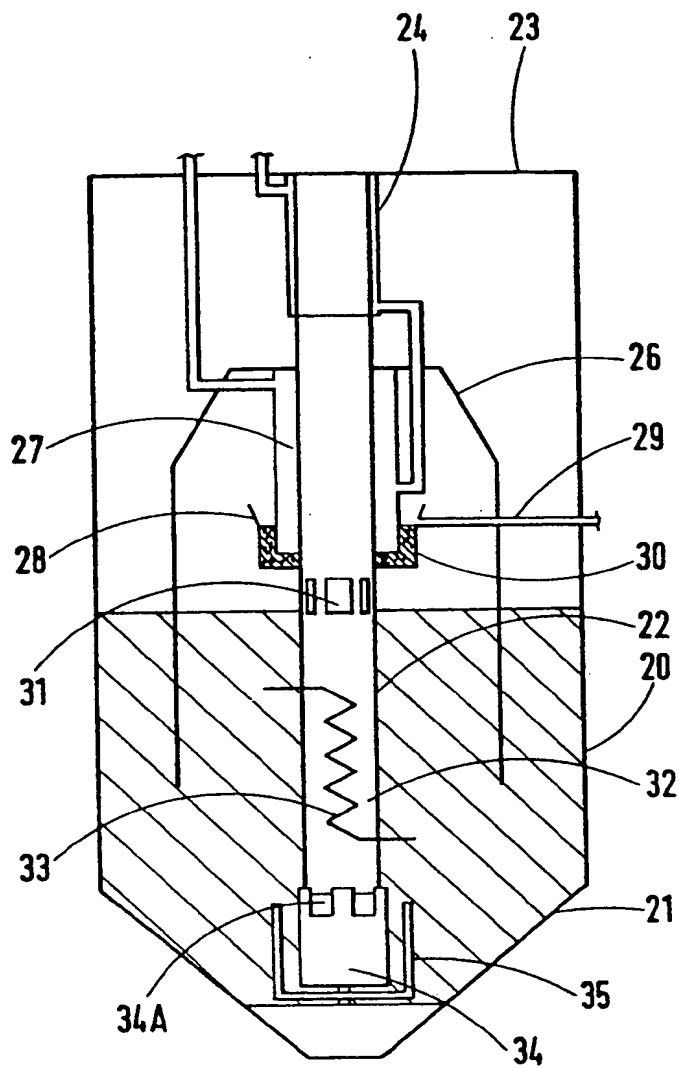


Fig.2

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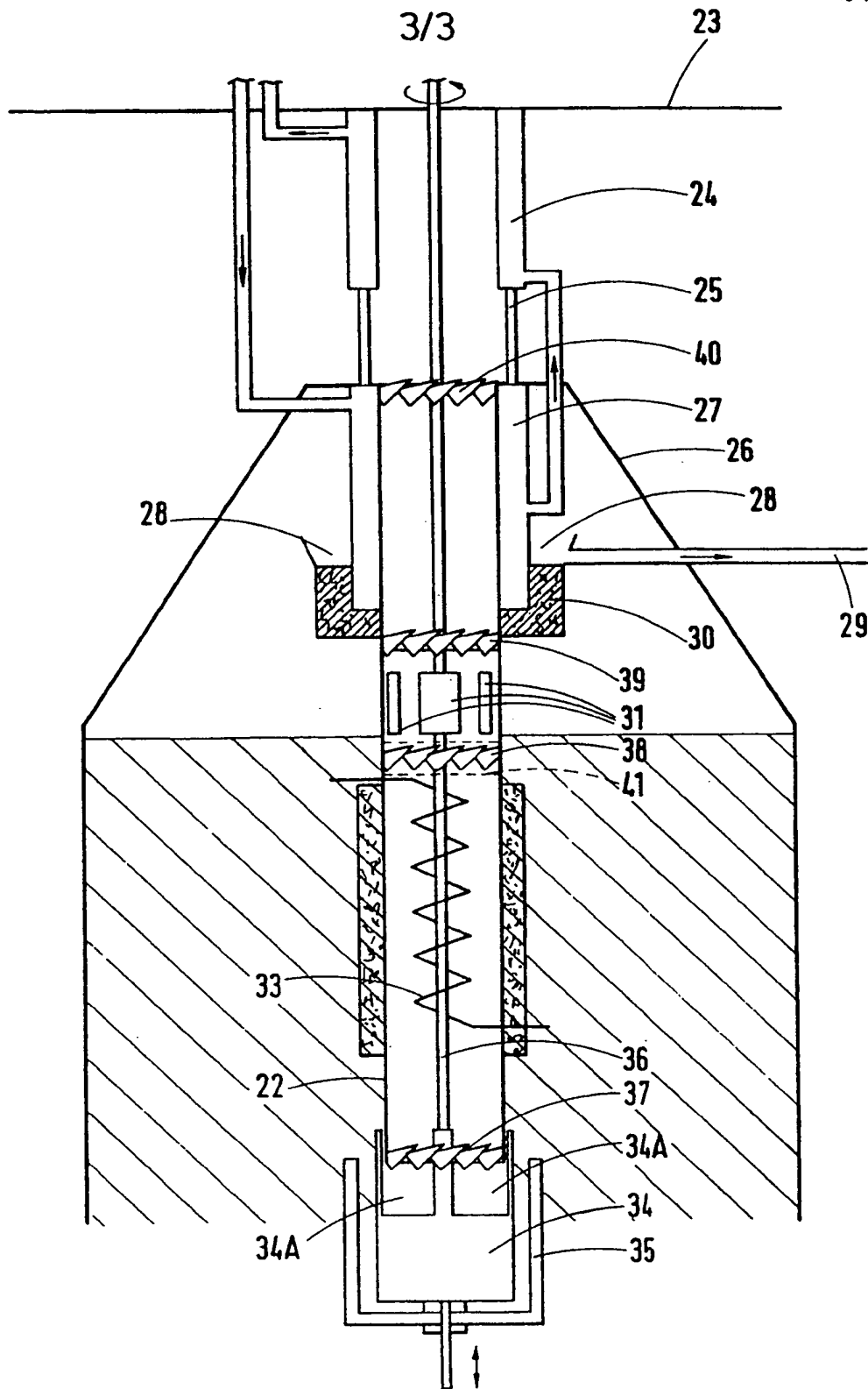


Fig.3

SPECIFICATION

Heat store system

5 This invention relates to heat storage systems and provides a method of storage of heat using reversible chemical reactions.

Known heat storage systems utilise the sensible heat stored in a solid or liquid such as tanks of water or heat storage bricks such as are commonly used in a system in which cheap rate electricity is stored for use during times when peak rates prevail. The disadvantage of heat storage systems utilising sensible heat only is that a large mass of heat storage material is required, since the amount of heat which can be stored is determined by the specific heat of the material and the mass available.

20 Phase change materials (PCM) have also been used to store heat and these materials have the advantage that the latent heat of the phase change is stored in the system in addition to the sensible heat. It is, therefore, possible to utilise a smaller mass or volume of material for a given heat storage capacity. The present invention makes use of the heat storage capacity available from a reversible chemical reaction.

30 According to the present invention there is provided a method of storing and releasing heat energy utilising a reversible chemical reaction which comprises heating, in a chamber, a chemical compound which dissociates on heating to components which are capable of reacting exothermically to reform the compound, removing one of the components from the chamber and recovering sensible heat from said components and releasing heat stored in the system by introducing said one component into the chamber to cause the exothermic reaction to proceed and recovering heat from the heat of reaction.

The most convenient reversible chemical reaction which has been studied is the reaction of calcium oxide and water as follows:



50 This reaction is exothermic and releases 63kJ/g of component reactants. This is a comparatively large heat capacity and represents approximately 6 times the heat available from a typical phase change material on a comparative weight basis. Thus, the volume of the heat store utilising a reaction such as calcium oxide with water is very much smaller than that possible with conventional heat storage systems.

60 The reaction of calcium oxide with water is easily reversed by heating calcium hydroxide to approximately 580°C, when calcium oxide and water are reformed. By calculation, it can be shown that utilising a heat store containing 65 28.1 kg of calcium oxide, the total theoretical

heat of reaction available is about 31.4 MJ (8.7 kWh). Since one of the components formed by heating calcium hydroxide is water (or steam at 500°C) this component is readily removed and its heat content can also be recovered during the conversion of the calcium hydroxide to calcium oxide. It is also possible during the formation of the calcium oxide to recover the sensible heat of the calcium oxide as it cools from approximately 580°C to room temperature.

A further advantage of the calcium oxide/water system is that the heat is stored at ambient temperature and is readily recovered simply by spraying the calcium oxide with water.

Reference is made to the drawings, in which:

Figure 1 shows one embodiment of the heat storage system utilising the heat stored in the calcium/oxide water reaction;

Figure 2 shows an alternative embodiment of the heat storage system; and

Figure 3 is an enlarged view of the central part of the apparatus shown in figure 2.

Referring first to Figure 1, the heat storage system comprises 3 chambers or containers labelled A, B and C. The upper container holds CaO in which is lying an electrical heater D., a heat exchanger coil A2, and a sparge pipe A1. Container B is a water filled container with heat exchange coil fed from the cavity at the top of the container A and the coil A2. The coil in B is open ended and discharges into container C which is a sump or reservoir containing water. The container marked AA is a fan assisted air/water heat exchanger shown diagrammatically in the return circuit to container B. Container B is used to feed a heating load such as central heating radiators, using P2. A suggested sequence of events is as follows.

If the upper container holds an amount of Ca(OH)_2 which is heated by heater D to 580°C, dissociation takes place and steam is driven off into the cavity at the top of A. This steam will pass through the coil in container B and give up its latent heat to the water container therein. When dissociation is complete, the heater is switched off, and the fan assisted heat exchanger AA is energised to cool the container and extract the sensible heat from the CaO. The coil would possibly be connected to the return from a heating system to pre-heat the water in cylinder B.

The CaO in the upper container is now activated by water being pumped up from the sump C via the sparge pipe A1 in the upper container, the amount of water being controlled by the valve V1. At the same time, this water will circulate through the coil A2 where it will take the heat of reaction and return to the sump through the coil in B, heating the water in B as it does so. When the reaction ceases the pump P1 will stop and the

system is ready to recommence. The small separate tank shown feeding the sump C is to top up the water in the heat exchange system as required.

- 5 Since the system allows an apparent gain in energy over the cycle, due to recovery of sensible and latent heats, and the heat of reaction is available even from cold, the system could offer considerable reductions in volumes of
10 store, especially on the part where the CaO at room temperature will not lose heat to the air whilst still having latent heat components.

Figures 2 and 3 show an alternative heat storage system which also utilises the calcium oxide/water reaction. The system comprises an outer container 20 having a generally funnel-shaped lower end 21 and initially containing powdered calcium hydroxide to a depth of approximately half the height of the container.

- 20 A central tube 22 extends centrally within the container 20 from a level within the funnel-shaped lower end 21 of the container to the top closure plate 23 thereof. Adjacent to the upper end thereof the tube 22 is surrounded
25 by an auxiliary heat exchange jacket 24, beneath which are circumferential openings 25 in the tube. A deflector 26 is mounted around the tube, preferably coaxially therewith, immediately beneath the openings 25, and extends
30 downwardly beneath the surface of the powder.

- A main heat exchange jacket 27 surrounds the upper part of the tube within the deflector 26, and is connected in series with the auxiliary jacket 24 so that heat exchange fluid (suitably water) flows from a heat load, through the main jacket 27, and then through the auxiliary jacket 24 before being returned to the heat load (e.g. space heating convectors/radiators). An annular collecting gutter 28 surrounds the lower part of the main heat exchange jacket 27 to collect condensate therefrom. The gutter 28 is provided with an outlet pipe 29, and insulation material 30 is provided
45 around the lower end of the main jacket 27 and on the underside of the gutter 28 to prevent condensation of vapour leading to water dripping back on to the powder inside the deflector 26. Vapour outlets 31 are provided
50 around the tube beneath the insulation 30, at a level just above the level of powder in the container.

- The portion of the tube beneath the outlets 31 forms a heating chamber 32 containing an electric heating element 33 (or other heating means operating at a suitable temperature). A lifting cup 34 is arranged as a sliding fit over the lower end of the tube and is provided with openings 34A around the upper part thereof, which openings serve to admit powder to the cup 34 when it is in its fully lowered position. A rotary agitator 35 is provided to maintain fluidity of the powder around the cup.

- 65 Referring to Figure 3, a drive and lifting

- shaft 36 is provided along the axis of the tube 22 and passes at its uppermost end through the top closure plate 23 to be connected to rotary drive and lifting means (not shown). The lifting cup 34 and the agitator 35 are mounted adjacent to the lowermost end of the shaft 36 in such a manner that the agitator 35 rotates with the shaft, while the cup remains stationary, and both are liftable. Additionally, four multi-bladed screw lifting devices 37, 38, 39 and 40 serving as non-return valves for the upward powder flow, are mounted on the shaft 36. The first of these screw devices 37 is slidably mounted on the shaft in the lower end of the tube so as to rotate with the shaft but remain in the same vertical position when the shaft is lifted to lift the cup 34 and agitator 35. The third and fourth screw devices (39 and 40 respectively) are similarly mounted at lower and upper ends of the main heat exchange jacket 27, while the second screw device 38 is arranged to rotate and lift with the shaft 36, at a rest position just beneath the vents 31. A slidable sleeve 41 is provided within the tube to close the vents 31 when the screw device 38 is lifted. This sleeve 41 can either be coupled to the shaft 36 or provided with separate lifting means to be liftable independently of the shaft 36.

- Energy is stored by and recovered from the system in the manner hereinafter described with particular reference to Figure 3. With the shaft 36 constantly rotating, the powder, the cup 34, in its lowermost position, fills with the powdered calcium hydroxide. The shaft 36 is then lifted to urge the powder in the cup 34 through the rotating screw device 37 and into the heating chamber 32. The screw device 37 acts as a non-return valve for the powder, and the cup 34 can be lowered for re-filling. The operation is repeated until the heating chamber 32 is full of powder. Rotation of the shaft is now ceased.

- The heating coil 33 is then heated so as to heat the chamber to a temperature of about 600°C. This causes the calcium hydroxide to dissociate into water, in the form of steam, and calcium oxide (quicklime). The body of calcium hydroxide surrounding the heating chamber 32 serves as thermal insulation, as it is a poor conductor of heat, and thus the need for external insulation for the system is reduced. Further heat losses from the chamber to the surrounding powder simply serve to pre-heat the powder before it enters the heating chamber.

- The steam released by the reaction in the heating chamber issues from the vapour outlets 31 and is condensed on the external surface of the heat exchange jacket 27, thereby giving up latent heat of vapourisation to the water (or other fluid) circulating through the jacket. The dense packing and relative high temperature of powder in tube above the out-

lets 31 keeps the risk of any reaction with or escape of the steam to a minimum. The condensate runs into the gutter 28 and is removed via the pipe 29 to be held for re-use.

5 When the reaction is completed, the outlets 31 closed by the sleeve 41, and fresh calcium hydroxide is loaded into the heating chamber, using the cup 34 as before. This has the effect of urging the hot calcium oxide from the heating chamber upwardly, the second screw device 38 lifting with the shaft to lift portions of the calcium oxide upwardly through the third screw device 39 and into the portion of the tube surrounded by the main heat ex-
10 change jacket 27. Further heat is passed into the circulating water, from the hot calcium oxide.

At the same time, the fresh batch of calcium hydroxide in the heating chamber is being reacted. On completion of the dissociation reaction, the lifting operation is repeated, and as hot calcium oxide is urged into the main heat exchange part of the tube, cooled calcium oxide is displaced from the uppermost
20 part, through the screw device 40 and out through the openings 25 to fall down the outside of the deflector 26 back onto the body of the powder. This sequence of operations is continued until substantially all the calcium hydroxide has been converted to calcium oxide, or until sufficient energy has been stored.

For recovery of the energy, the condensed water is supplied in measured doses to the upper end of the portion of the tube within the heat exchange jacket 27, causing an exothermic reaction as calcium oxide is reconverted to calcium hydroxide (quicklime to slaked lime). Any steam produced in the reaction is condensed by the auxiliary heat exchange jacket 24 and drips back into the calcium oxide being reacted. In this way, latent heat of vapourisation is recovered in the circulating fluid, as well as the sensible heat of reaction within the main heat exchange jacket. When
35 the reaction is completed, fresh calcium oxide is lifted through the tube into the main heat exchange portion, displacing the calcium hydroxide, which falls through the openings 25 back on to the powder surrounding the lower part of the deflector 26. This sequence of operations can be repeated in accordance with heat demand at the load, to which the heat exchange jackets 24 and 27 are in fluid slow connection.

55 It should be noted that the powder remains dry in all stages of the system, as the reaction is from calcium oxide (CaO) to calcium hydroxide (Ca(OH)_2). The latent energy of the calcium oxide can be stored as cold powder for as long as necessary.

60 Although the present invention has been described with particular reference to the calcium oxide system, it will be appreciated that other reversible reactions could also be utilised for heat storage in an analogous manner.

CLAIMS

1. A method of storing and releasing heat energy utilising a reversible chemical reaction, which comprises heating a chemical compound which dissociates on heating to separable components which are capable of reacting exothermically to reform the compound, removing one of the components from the chamber recovering sensible heat from said components, releasing heat stored in the system by mixing said one component with the other component to cause the exothermic reaction to occur, and recovering heat from the heat of reaction.

2. A method according to the Claim 1, wherein said one component is water.

3. A method according to Claim 2, wherein the dissociation reaction produces steam, which is then condensed to recover the latent heat of vapourisation.

4. A method according to any preceding claim, wherein the chemical compound is calcium hydroxide.

5. A method of storing and releasing heat energy, substantially as described with reference to the drawings.

6. Apparatus for storing and releasing heat energy, comprising a chamber containing a chemical compound which dissociates on heating to separable components which are capable of reacting exothermically to reform the compound, a heater within the chamber for introducing heat energy to the compound to cause dissociation thereof, separating means for removing one of said components from the chamber, mixing means for reintroducing the said one component to the other component in the chamber, and a heat exchanger for recovering the heat of reaction when the two components are reacted.

7. Apparatus according to Claim 6, wherein the separating means comprise a vapour outlet from the chamber and a heat exchanger to condense the vapour and transfer heat to a heating circuit.

8. Apparatus according to Claim 6, wherein transport means are provided for transporting the chemical compound from a reservoir to the chamber to be heated, then to a heat exchanger wherein sensible heat is removed, and then back to the reservoir, the separating means comprising a condenser for the said one component liberated in the vapour phase.

9. Apparatus according to Claim 8, wherein the chamber and the heat exchanger comprise portions of a vertical tube extending from within the reservoir to an opening above a deflector surrounding the tube and arranged to return the component or compound discharged from the tube to an outer portion of the reservoir.

10. Apparatus according to Claim 9, wherein flow of powdered material up the tube is controlled by rotatable multi-bladed

screw devices which permit upward passage of powder but resist downward passage of powder.

11. Apparatus for storing and releasing heat
5 energy, substantially as described with reference to, or as shown in, Figure 1 or Figures 2 and 3 of the drawings.

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